Spitzer Space Telescope Observations of Low Mass X-ray Binaries

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Abstract. We present preliminary results from our archival Spitzer Space Telescope program aimed at characterizing the mid-IR properties of compact objects, both isolated and in binary systems, i.e. white dwarfs, X-ray binaries, cataclysmic variables, and magnetars. Most of these sources are too faint at mid-IR wavelengths to be observable from the ground, so this study provides the very first comprehensive look at the mid-IR emission of these objects. Here we present our results for the low mass X-ray binaries (LMXBs). We considered all of the systems listed in the most recent catalog of Liu et al. (2007) that have known optical counterparts. The particular goals of our projects encompass: to establish the mid-IR spectral energy distribution, to search for the signatures of jets, circumbinary disks, low mass or planetary companions and debris disks, and to study the local environment of these sources.

1. Introduction

We have searched the Spitzer Space Telescope archive (with *Leopard*) for observations covering the positions of all low mass X-ray binaries with known optical counterparts listed in Liu et al. (2007). Table 1 details the data available for each source as of March 21, 2008. Note that not all of the data listed in the table are public at the time of this writing. Accepted Cycle 5 programs are listed, but not yet observed. In Table 2 we provide results as to whether a particular source is detected or not, together with published Spitzer measurements of LMXBs. In this context, (f) denotes faint, in a most subjective fashion. (s) indicates that some pixels of the source PSF are saturated. We have found 17 newly detected sources in addition to the eight published Spitzer detections of LMXBs. Photometry of these sources is still ongoing and will be published at a later date.

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Table 1.   LMXBs observed by the Spitzer Space Telescope

Name[a]	Altern. Name	RA (2000)	DEC (2000)	PID/AORkey, Instr. Mode, Notes
IGR J00291+5934		00 29 03.06	59 34 19.00	No programs found
4U 0042+32		00 44 50.40	33 01 17.00	No programs found
GRO J0422+32		04 21 42.79	32 54 27.10	40948/23365888 IRAC Mapping
2A 0521−720	LMC X−2	05 20 28.13	−71 57 35.34	20203/14358272 IRAC Mapping
				20203/14370816 IRAC Mapping
				20203/14356480 IRAC Mapping
				20203/14371072 IRAC Mapping
				20203/14390016 MIPS Scan Map
				20203/14383104 MIPS Scan Map
				20203/14383360 MIPS Scan Map
				20203/14389760 MIPS Scan Map
4U 0614+091		06 17 07.40	09 08 13.60	20224/14415872 IRAC Mapping
				30803/19018240 IRAC Mapping
				30803/19018496 MIPS Photometry
1A 0620−00		06 22 44.50	−00 20 44.72	3289/10702592 MIPS Photometry
				3289/10703616 IRAC Mapping
				30616/18618112 IRAC Mapping
				30616/18618624 IRAC Mapping
EXO 0748−676		07 48 33.80	−67 45 08.93	No programs found
4U 0919−54		09 20 26.95	−55 12 24.70	20224/14416128 IRAC Mapping
2S 0921−630		09 22 34.73	−63 17 41.37	No programs found
XTE J0929−314		09 29 20.19	−31 23 03.20	No programs found
GRS 1009−45		10 13 36.30	−45 04 32.00	40948/23364864 IRAC Mapping
XTE J1118+480		11 18 10.85	48 02 12.90	3289/10702848 MIPS Photometry
				3289/10703872 IRAC Mapping
GS 1124−684		11 26 26.70	−68 40 32.60	40948/23365376 IRAC Mapping
1A 1246−588		12 49 39.36	−59 05 14.68	No programs found
4U 1254−69		12 57 37.20	−69 17 20.80	No programs found
4U 1323−62		13 26 36.31	−62 08 09.90	190/9231616 IRAC Mapping
				190/9234176 IRAC Mapping
				20597/15646208 MIPS Scan Map
				20597/15657216 MIPS Scan Map
GS 1354−64		13 58 09.92	−64 44 04.90	No programs found
4U 1456−32	Cen X−4	14 58 22.00	−31 40 08.00	3289/10703360 MIPS Photometry
				3289/10704384 IRAC Mapping
3A 1516−569	Cir X−1	15 20 40.90	−57 10 01.00	190/9226752 IRAC Mapping
				190/9228032 IRAC Mapping
				191/9331200 IRAC Mapping
				20597/15593984 MIPS Scan Map
				20597/15626240 MIPS Scan Map
1A 1524−61	TrA X−1	15 28 17.20	−61 52 58.00	50477/26257920 MIPS Scan Map
4U 1543−47		15 47 08.60	−47 40 10.00	No programs found
4U 1543−624		15 47 54.29	−62 34 05.13	20224/14415616 IRAC Mapping
XTE J1550−564		15 50 58.78	−56 28 35.00	No programs found
4U 1556−60		16 01 02.30	−60 44 18.00	No programs found
1E 1603.6+2600		16 05 45.82	25 51 45.10	No programs found
4U 1608−52		16 12 43.00	−52 25 23.00	191/9329664 IRAC Mapping
				191/9334784 IRAC Mapping
				20597/15606016 MIPS Scan Map
				20597/15653632 MIPS Scan Map
				30570/20252928 IRAC Mapping
H 1617−155	Sco X−1	16 19 55.07	−15 38 24.80	20462/14727168 IRAC Mapping
				20462/14727424 MIPS Photometry
				20462/14727680 IRS Peakup Image
				50600/26536192 IRS Staring
4U 1624−49		16 28 02.83	−49 11 54.61	191/9334528 IRAC Mapping
				20597/15610880 MIPS Scan Map
				20597/15620608 MIPS Scan Map
4U 1626−67		16 32 16.80	−67 27 43.00	20224/14415360 IRAC Mapping
4U 1630−47		16 34 01.61	−47 23 34.80	191/9326592 IRAC Mapping
				191/9330688 IRAC Mapping
				20597/15645184 MIPS Scan Map
				20597/20489984 MIPS Scan Map
				20597/15660800 MIPS Scan Map
				20597/20489728 MIPS Scan Map
4U 1636−536		16 40 55.50	−53 45 05.00	No programs found
XTE J1650−500		16 50 00.98	−49 57 43.60	No programs found

Table 1.   continued

Name[a]	Altern. Name	RA (2000)	DEC (2000)	PID/AORkey, Instr. Mode, Notes
GRO J1655−40		16 54 00.14	−39 50 44.90	3246/10524928 MIPS Photometry
				3246/10525184 MIPS Photometry
				3246/10525696 MIPS Photometry
				3246/10525440 MIPS Photometry
				20301/14508800 IRAC Mapping
				20301/14509312 MIPS Photometry
				20669/14967040 IRAC Mapping
				30570/20220416 IRAC Mapping
				30570/21312768 IRAC Mapping
				30570/21311232 IRAC Mapping
2A 1655+353	Her X−1	16 57 49.83	35 20 32.60	No programs found
XTE J1701−462		17 00 58.45	−46 11 08.60	30570/21285376 IRAC Mapping
MXB 1659−298		17 02 06.50	−29 56 44.10	No programs found
4U 1659−487	GX339−4	17 02 49.50	−48 47 23.00	3246/10524416 MIPS Photometry
				3246/10524672 MIPS Photometry
3A 1702−363	GX349+2	17 05 44.50	−36 25 23.00	30570/20246528 IRAC Mapping
				30570/21296384 IRAC Mapping
				30570/21324544 IRAC Mapping
				50670/26686976 MIPS Photometry
				50670/26687488 IRAC Mapping
4U 1702−429		17 06 15.31	−43 02 08.69	No programs found
4U 1700+24		17 06 34.52	23 58 18.60	No programs found
4U 1705−250		17 08 14.60	−25 05 29.00	No programs found
XTE J1709−267		17 09 30.40	−26 39 19.90	No programs found
IGR J17098−3628		17 09 45.93	−36 27 58.20	30570/20246528 IRAC Mapping
				30570/21296384 IRAC Mapping
				30570/21324544 IRAC Mapping
GRO J1719−24		17 19 36.93	−25 01 03.40	No programs found
XTE J1720−318		17 19 58.99	−31 45 01.25	50477/26273280 MIPS Scan Map
IGR J17269−4737		17 26 49.28	−47 38 24.90	No programs found
4U 1728−16	GX 9+9	17 31 44.20	−16 57 42.00	No programs found
4U 1728−34	GX 354−0	17 31 57.73	−33 50 02.50	20201/14292992 IRAC Mapping
				20201/14293248 IRAC Mapping
				20201/14323200 IRAC Mapping
				20201/14322944 IRAC Mapping
3A 1728−247	GX 1+4	17 32 02.16	−24 44 44.00	20119/14093056 IRAC Mapping
				20119/14099456 MIPS Scan Map
				20119/14099712 MIPS Scan Map
KS 1731−260		17 34 13.47	−26 05 18.80	20119/14090496 IRAC Mapping
				20119/14099968 MIPS Scan Map
				20119/14100480 MIPS Scan Map
				30570/21277184 IRAC Mapping
				30570/21335552 IRAC Mapping
				30570/21291776 IRAC Mapping
				30570/21307136 IRAC Mapping
4U 1735−444		17 38 58.30	−44 27 00.00	No programs found
1H 1743−322		17 46 15.57	−32 14 01.10	30570/20205824 IRAC Mapping
				30570/20210432 IRAC Mapping
				30570/21306624 IRAC Mapping
				30570/21313024 IRAC Mapping
				30594/20515840 MIPS
				30594/20517888 MIPS
				30594/20516864 MIPS
IGR J17473−2721		17 47 18.08	−27 20 38.70	20201/14309888 IRAC Mapping
				20201/14309632 IRAC Mapping
				20201/14339328 IRAC Mapping
				20201/14339584 IRAC Mapping
				20414/14658048 MIPS Scan Map
				20414/14659072 MIPS Scan Map
1A 1744−361		17 48 13.15	−36 07 57.02	No programs found
IGR J17497−2821		17 49 38.04	−28 21 17.37	3677/13368320 IRAC Mapping
				3677/13370624 IRAC Mapping
				20201/14308096 IRAC Mapping
				20201/14337792 IRAC Mapping
				20414/14657792 MIPS Scan Map
				20414/14658048 MIPS Scan Map
EXO 1747−214		17 50 24.52	−21 25 19.90	30570/20208640 IRAC Mapping
4U 1755−33		17 58 40.00	−33 48 27.00	No programs found
4U 1758−25	GX 5−1	18 01 08.22	−25 04 42.46	20201/14314752 IRAC Mapping
				20201/14312704 IRAC Mapping
				20201/14342400 IRAC Mapping
				20201/14344448 IRAC Mapping
				30570/21293568 IRAC Mapping

Table 1.   continued

Name[a]	Altern. Name	RA (2000)	DEC (2000)	PID/AORkey, Instr. Mode, Notes
GRS 1758−258		18 01 12.40	−25 44 36.10	20201/14312192 IRAC Mapping
				20201/14341888 IRAC Mapping
SAX J1808.4−3658		18 08 27.60	−36 58 43.90	No programs found
SAX J1810.8−2609		18 10 44.47	−26 09 01.20	No programs found
XTE J1814−338		18 13 39.04	−33 46 22.30	No programs found
4U 1811−17	GX 13+1	18 14 31.55	−17 09 26.70	146/12104192 IRAC Mapping
				146/12108800 IRAC Mapping
				20597/15598848 MIPS Scan Map
				20597/15634944 MIPS Scan Map
				20597/15632384 MIPS Scan Map
4U 1812−12		18 15 06.16	−12 05 46.70	30570/21288448 IRAC Mapping
				30570/21309440 IRAC Mapping
4U 1813−14	GX 17+2	18 16 01.39	−14 02 10.62	50670/26686720 MIPS Photometry
				50670/26687744 IRAC Mapping
AX J1824.5−2451		18 24 30.00	−24 51 00.00	40111/21745408 IRS Staring
4U 1823−00		18 25 22.02	−00 00 43.00	20224/14415104 IRAC Mapping
2A 1822−371		18 25 46.80	−37 06 19.00	1867/16040192 MIPS Scan Map
				1867/16040448 MIPS Scan Map
				1867/16040704 MIPS Scan Map
				1867/16040960 MIPS Scan Map
				1867/16041216 MIPS Scan Map
				1867/16041472 MIPS Scan Map
				1867/16041728 MIPS Scan Map
				1867/16041984 MIPS Scan Map
				1867/16042240 MIPS Scan Map
				1867/16042496 MIPS Scan Map
				1867/16042752 MIPS Scan Map
				1867/16043008 MIPS Scan Map
				1867/16043264 MIPS Scan Map
				1867/16043520 MIPS Scan Map
				1867/16043776 MIPS Scan Map
				1867/16044032 MIPS Scan Map
				1867/16044288 MIPS Scan Map
				1867/16044544 MIPS Scan Map
				1867/16044800 MIPS Scan Map
				1867/16045056 MIPS Scan Map
				1867/16057856 MIPS Scan Map
				1867/16058112 MIPS Scan Map
				1867/16058368 MIPS Scan Map
GS 1826−238		18 29 28.20	−23 47 49.12	No programs found
2A 1837+049	Ser X−1	18 39 57.56	05 02 09.60	174/5716992 MIPS Scan Map
				BUT: position of LMXB not covered
XTE J1859+226		18 58 41.58	22 39 29.40	40948/23365120 IRAC Mapping
HETE J1900.1−2455		19 00 08.65	−24 55 13.70	No programs found
4U 1905+000		19 08 26.97	00 10 07.70	No programs found
XTE J1908+094		19 08 53.08	09 23 04.90	187/11963904 IRAC Mapping
				20597/15614720 MIPS Scan Map
4U 1908+005	Aql X−1	19 11 16.00	00 35 06.00	No programs found
GRS 1915+105		19 15 11.55	10 56 44.76	187/11970048 IRAC Mapping
				187/11973120 IRAC Mapping
				3352/10831616 IRAC Mapping
				3352/10832128 IRS Staring
				3352/10832384 IRS Staring
				3352/10832640 IRS Staring
				3352/10832896 IRS Staring
				3352/10831360 IRAC Mapping
				3352/10831104 IRAC Mapping
				3352/10831872 IRAC Mapping
				20232/14420480 IRAC Mapping
				20232/14420736 IRAC Mapping
				20232/14420992 IRAC Mapping
				20232/14420224 IRAC Mapping
				20232/14421248 IRS Staring
				20232/14422016 IRS Staring
				20232/14421504 IRS Staring
				20232/14421760 IRS Staring
				20597/15599616 MIPS Scan Map
				20597/15614976 MIPS Scan Map
4U 1916−05		19 18 47.87	−05 14 17.09	20224/14414848 IRAC Mapping
3A 1954+319		19 55 42.33	32 05 49.10	No programs found
4U 1957+11		19 59 24.20	11 42 32.40	No programs found

Table 1. continued

Name[a]	Altern. Name	RA (2000)	DEC (2000)	PID/AORkey, Instr. Mode, Notes
GS 2000+25		20 02 49.58	25 14 11.30	40948/23365632 IRAC Mapping
XTE J2012+381		20 12 37.71	38 11 01.10	20726/15055616 MIPS Photometry
				20726/15055872 IRAC Mapping
GS 2023+338		20 24 03.80	33 52 03.20	3289/10703104 MIPS Photometry
				3289/10704128 IRAC Mapping
XTE J2123−058		21 23 14.54	−05 47 53.20	No programs found
4U 2129+47		21 31 26.20	47 17 24.00	No programs found
4U 2142+38	Cyg X−2	21 44 41.20	38 19 18.00	50670/26687232 MIPS Photometry
				50670/26688000 IRAC Mapping

[a]nomenclature from Liu et al. (2007)

Table 2. Results

Name	F3.6 (mJy)	F4.5 (mJy)	F5.8 (mJy)	F8.0 (mJy)	F24 (mJy)	Notes
LMC X−2	0.038	yes(f)	no	no	no	SAGE Winter'07 catalog, this work
X0614+091	0.16	0.18	0.2	0.25	yes	Migliari et al. 2006; this work (24μm)
X0620−003	...	0.4	...	0.29	0.14	Gallo et al. 2007
	...	0.45	...	0.25	0.05	Muno et al. 2006
X0918−549	no	no	no	no	...	this work, north component of pair detected
J1118+480	...	0.069	...	0.059	< 0.05	Gallo et al. 2007
	...	0.046	...	0.045	< 0.02	Muno et al. 2006
X1323−62	no	no	no	no	no	Counterpart uncertain
Cen X−4	...	0.20	...	0.095	< 0.03	Muno et al. 2006
Cir X−1	18.55	15.26	12.40	8.75	6	GLIMPSE Spring'07 catalog, this work (24μm)
X1543−62	no	no	no	no	...	this work
X1608−52	yes(f)	yes(f)	no	no	no	this work, very crowded
Sco X−1	10	7	4	1.5	1	Wachter et al. 2006
X1624−490	no	no	no	no	no	this work, very crowded
X1626−67	yes(f)	yes(f)	yes(f)	no	...	this work
X1630−47	no	no	no	no	no	this work, too crowded
X1655−40	5.67	3.90	3.02	2.40	< 0.54 − 2.07	Migliari et al. 2007
GX 339−4	...	...	...	...	0.135	Tomsick et al. 2004
XJ1701−462	yes	yes	yes	yes	...	this work, correct ctpt?
GX 349+2	yes	yes	yes	yes(f)	...	this work
IGR J17098−3628	no	no	no	no	...	this work, too crowded
GX 354−0	yes(f)	yes(f)	yes(f)	no:	...	this work
GX 1+4	yes(s)	yes	yes	yes	yes	this work, saturated ch1
X1731−260	no	no	no	no	no	this work, close neighbor detected
X1743−322	yes(f)	yes(f)	yes(f)	no	no	this work, blend of three sources, too crowded
IGR J1747−2721	no	no	no	no	no	this work, too crowded
IGR J17497−2821	yes(f):	yes(f):	yes(f):	no	no	this work, too crowded
X1747−214	...	no	...	no	...	this work, ctpt uncertain, blend of 3 sources
GX 5−1	yes	yes	no:	no	...	this work, close blend of two sources
X1758−258	yes	yes	yes	no	...	this work
GX 13+1	7.82	6.13	4.20	2.49	no	GLIMPSE Spring'07 catalog, this work (24μm)
X1812−12	yes(f):	yes(f):	yes(f)	no	...	this work
X1822−00	yes(f)	yes(f)	yes(f)	no	...	this work
XTE J1908+094	no	no	no	no	no	this work, too crowded
X1915+105	4.66	4.96	4.63	2.96	28.3	GLIMPSE Spring'07 catalog, this work (24μm)
X1916−05	yes	yes	yes(f)	yes	...	this work, blended with neighbor
XTE J2012+381	yes	yes	no	no	no	this work, blended with neighbor
V404 Cyg	...	3.3	...	1.8	0.4	Gallo et al. 2007
	...	3.0	...	1.45	1.53	Muno et al. 2006

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